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CIVIL AERONAUTICS BOARD

AIRCRAFT ACCIDENT REPORT

ADOPTED: December 11, 1962 | **RELEASED:** December 18, 1962

TRANS WORLD AIRLINES, INC., LOCKHEED CONSTELLATION, MODEL 049,
N 86511, MIDWAY AIRPORT, CHICAGO, ILLINOIS
SEPTEMBER 1, 1961

SYNOPSIS

Trans World Airlines Flight 529, a model 049 Lockheed Constellation, N 86511, crashed about nine miles west of Midway Airport, Chicago, Illinois, on September 1, 1961, at 0205 c.d.t., killing all 78 occupants.

The flight originated at Boston, Massachusetts, destination San Francisco, California, with intermediate stops scheduled at New York, New York; Pittsburgh, Pennsylvania; Chicago, Illinois; Las Vegas, Nevada; and Los Angeles, California. The flight to Chicago was routine.

A scheduled crew change was made at Chicago and the flight departed there at 0200 c.d.t. Approximately five minutes later, during good weather, while climbing on the intended course, the aircraft experienced loss of longitudinal control and crashed. All occupants died instantly and the aircraft was completely destroyed.

Investigation disclosed that a 5/16-inch AN-175-21 nickel steel bolt from the elevator boost mechanism was missing. There was evidence that the bolt was not in place at the time of impact. The proper positioning of this bolt is vital to the control of the aircraft and must therefore have been in place until immediately prior to the loss of control.

The Board determines that the probable cause of this accident was the loss of an AN-175-21 nickel steel bolt from the parallelogram linkage of the elevator boost system, resulting in loss of control of the aircraft.

Investigation

At approximately 0205[1/], September 1, 1961, a Trans World Airlines Lockheed Constellation 049, N 86511, crashed approximately nine miles west of Midway Airport, Chicago, Illinois, following takeoff from Midway Airport. The crew of 5 and all 73 passengers were fatally injured.

TWA Flight 529 was a scheduled flight originating at Boston, Massachusetts, with intermediate stops at New York, Pittsburgh, Chicago, Las Vegas, Los Angeles, and terminating at San Francisco, California.

1/ All times herein unless otherwise noted are Central Daylight based on the 24-hour clock.

Discrepancies noted prior to the Boston departure were an inoperable white navigation light located in the aircraft's tail cone, and a leaking fuel drain valve on the No. 3 main fuel tank sump. These two discrepancies were corrected by the ground crew prior to the flight's departure from Boston. One carry-over discrepancy from the previous flight was a malfunction of the cabin refrigeration system during ground operation. Since this was not considered necessary to the safety of flight, it was carried over to prevent a delay at Boston. Because of this discrepancy, the cabin was unpressurized during climbout until reaching 6,000 feet, at which time the cabin was pressurized to the field elevation of the next stop. This procedure was repeated after each en route stop to cool the cabin for passenger comfort.

The flight from Boston to Midway Airport, Chicago, was routine and it arrived there at 0118.

The crew originating the flight at Boston terminated their portion at Chicago. The new crew consisted of Captain James H. Sanders, First Officer Dale Tarrant, Flight Engineer James C. Newlin, and Stewardesses Barbara Jane Pearson and Nanette G. Fidger.

The incoming captain and flight engineer briefed Captain Sanders and Flight Engineer Newlin on the carry-over discrepancy and it was agreed that the aircraft was airworthy. At Midway, oil and fuel were added. Total fuel on board at departure was 3,240 gallons. The gross takeoff weight was 94,794 pounds - well below the maximum allowable gross takeoff weight of 96,000 pounds, and the center of gravity was within allowable limits. A flight plan to Las Vegas was filed for the flight in accordance with Instrument Flight Rules (IFR) via Victor Airway 8 to Akron, Colorado, Victor Airway 1512 to Kremmling, Colorado, Victor Airway 1522 to Mormon, Nevada, and Victor Airway 8-North to Las Vegas. The estimated time en route was six hours and twenty-three minutes, at a true airspeed of 223 knots.

When the aircraft departed the passenger loading gate, Captain Sanders was observed by a TWA passenger agent to have been seated in the left seat.

During engine runup, Flight 529 was given its air traffic control clearance which was: "cleared to the Las Vegas Airport via Victor 6 Naperville, Victor 8 flight plan route, maintain 5,000 feet." The clearance was acknowledged correctly and TWA Flight 529 departed on runway 22L at 0200, making a right turn out of traffic.

The 0200 Midway Airport weather was: scattered clouds at 10,000 feet; high overcast, visibility three miles in haze and smoke; wind south eight knots. The Chicago O'Hare Airport weather at 0200 was: partial obscuration; scattered clouds 15,000 feet; high overcast; visibility two and one-half miles in ground fog and smoke; wind south six knots.

Radar contact was established with the flight one minute and 34 seconds after the flight acknowledged takeoff clearance and as the aircraft proceeded outbound in a right turn. At 0204, Flight 529 was observed on radar by the departure controller to be five miles west of Midway Airport proceeding on course. Northwest Airlines Flight 105 was cleared for takeoff on runway 22L at Midway, and took off immediately. The ground controller observed a flash west of Midway Airport at this time and asked Flight 105 if he had seen a flash. Flight 105 advised that they had seen a flash fire and would fly over the area. As Flight 105 reported over the fire, the radar range was noted to be nine miles west of Midway Airport and the radar return of TWA

Flight 529 had disappeared from the scope. It was later determined that Flight 529 had crashed at this site and that the observed ground fire was the result of the accident.

At approximately 0204, American Airlines Flight 805, an air freighter, also observed the flash as they were about to land at Midway Airport. They abandoned their landing approach and proceeded to the fire area on a westerly course at an altitude of 2,000 feet with their landing lights on.

A door-to-door inquiry by members of the Civil Aeronautics Board witness group was accomplished over a localized area along the probable flightpath, resulting in approximately 150 interviews.

Witnesses who observed Flight 529 indicated that it was heading in a westerly direction and was apparently proceeding normally until less than two miles from the scene of the accident. A witness located one mile south-southwest of the scene stated that the aircraft was flying low at that point on a northerly heading. No witnesses were found who saw the aircraft at the moment of impact; however, a few witnesses located near the accident scene said that they heard a change in engine noise volume, but that this change in engine sound did not indicate to them either distress or failure. Other witnesses were confused by the presence of other aircraft flying in the area immediately following the accident and therefore were unable to determine definitely if they had seen Flight 529.

TWA Flight 529 crashed in an open field near Hinsdale, DuPage County, Illinois. The aircraft struck the ground in a slightly left-wing-low and nosedown attitude on a heading of approximately true North. The aircraft disintegrated, leaving debris over an area 200 feet wide and 1,100 feet long. Five craters were made, each approximately three to four feet deep, as a result of the four engines and fuselage striking the ground.

Investigation revealed that the portion of the horizontal stabilizer to which the right vertical fin is attached had separated from the aircraft prior to impact, having landed approximately 400 feet south of the main impact craters. The stabilizer failure occurred at Stabilizer Stations 240R and 230R of the front and rear spars, respectively. There was no evidence of fatigue on the spar caps, spar webs, skin material, or stringers. Examination did disclose that there had been oscillatory loads applied to the four spar caps and the two spar webs prior to and during separation. The front spar upper and lower caps had failed in tension and the interconnecting spar web had experienced a tensile tear from top to bottom. The fracture faces of both rear spar caps were brinelled by recontact after failure.

There were several indications that the elevator had been at its maximum upward travel. The most significant evidence of this was in the deformation pattern impressed in the right rudder by the elevator outboard closing rib in a manner and position such that the elevator had to be full up at the time the right rudder was forced into it during the stabilizer separation.

The landing gear was determined to be in the up and locked position at impact. The flaps and landing lights were retracted, and all flight controls and their counterbalances were accounted for.

There was no evidence of in-flight fire; however, there was considerable evidence of ground fire on portions of the wreckage which also showed severe impact damage.

Examination of the wreckage revealed no evidence of an in-flight explosion or collision with foreign objects. No evidence of electrical overheating of the DC and AC units was found.

Measurements and readings were made of all trim actuators and their associated cockpit position indicators. The variations of readings within each of the trim systems prevented any determination of in-flight trim positions.

The two aileron boost assemblies were found in the boost-off position as was the aileron boost cutoff valve. The shift handle in the cockpit, however, was found in the boost-on position. Since the shifting mechanisms are interconnected by long lengths of cable subject to being pulled by fragmenting structure following impact, the position of the cockpit handle is considered to be the more reliable, but not positive, indication of aileron boost condition. Under functional testing, the components of the left aileron boost package functioned satisfactorily. The right aileron boost package was too badly fire damaged to be tested.

The position of the rudder boost shift handle could not be determined, but all affected components of the boost package were in the boost-on position. The components of the boost package functioned normally when tested.

The elevator boost shift handle was found in the on position as was the boost package. The components were functionally tested individually and found to operate satisfactorily, commensurate with the impact damage suffered by the unit, except for the disconnection of one link of the parallelogram, which is discussed below.

Examination of the parallelogram linkage of the elevator boost located in the extreme aft section of the fuselage revealed a 5/16-inch AN-175-21 nickel steel bolt to be missing. (See Appendix A, Fig. 1.) This parallelogram linkage connects the pilot elevator input to the control valve of the elevator boost system. The bolt was not found in the wreckage despite a thorough search, including sifting of earth in the wreckage area.

The arm assemblies, part No. 291089L, part No. 291089R, and link assembly, part No. 290790 (See Appendix A, Fig. 1), were examined to determine if the bolt was in place at time of impact. This bolt, when in its proper position, passes through the press-fit bushings of P/N 291089 arm assemblies and the P/N 290790 link assembly. The head of the bolt is installed against the outboard face of arm assembly P/N 291089L. On the outboard face of the bushing, which is flush with the face of the forged arm, there were two deposits of old thick grease having the consistency of modeling clay and 0.01 inch or more deep. (See Appendix A, Fig. 2.) The larger of the two grease deposits covered an arc of 120 degrees from the 11:00 to the 3:00 o'clock positions, 2/ and averaged 3/32 inch in width. The inner edge of this deposit was common with the inner circumference of the bushing, whereas the outer edge was, in places, slightly beyond the bushing's outer circumference; however, a slight outline of two sides of the bolt's hex-head was visible around its outer perimeter of the deposit. (See Appendix A, Fig. 2.)

2/ The clock positions were referenced by passing an imaginary line through the centers of the torque tube hole and the hole at the actuator end, the latter being in the direction of 12:00 o'clock. Thereafter, clock references were used as the part was being viewed at the time. Subcomponents such as the bushings were referenced by passing imaginary lines through their centers parallel to the reference line of the part and with the 12:00 o'clock and 6:00 o'clock ends consistent therewith.

The smaller deposit covered an arc of 60 degrees between the 7:00 and 9:00 o'clock positions and, like the larger deposit, the inner edge was common with the bushing's inner circumference and was about 3/32 inch wide.

There were many scuff marks across the faces of both deposits, but neither had received any compressive loads sufficient to flatten their top surfaces. Those portions of the bushing which had no heavy grease buildup showed a film of grease of the same consistency.

After cleaning the faces of the bushing, it was examined for scratches, brinelling and elongation. No elongation of the bushing hole could be found. On the bushing's inboard face there was a nick on the outer circumference at the 8:00 o'clock position measuring 0.020 x 0.045 inch and estimated to be 0.01 inch deep. Also present were light circumferential scratching and polishing. Three light longitudinal scratches could be seen in the bore of the bushing, but were not discernible when it was cleaned. At the outboard face of the bushing, surface scratches could be seen on the forging. The edge of these scratches was concentric with the circumference of the bushing and the approximate diameter of an AN-960-516 washer. It was noted, however, that the edges of the grease deposits had overlapped portions of this scratched area. Other than light concentric scratches, this face of the bushing showed no impact marks, brinelling, or denting.

On the inboard face of the arm assembly P/N 291089L at and near the edge, there was a deep gouge made by the sharp corner of the clevis of the P/N 290790 link assembly. The face of this gouge was generally triangular, and the maximum depth was 0.035 inch with definite chatter marks across the gouge face. Along two sides of the triangle the edges were sawtoothed in shape, showing some of the individual cycles of chatter. The bolt hole at the opposite end of the link would not line up with the arm assembly bushing when the clevis was aligned with any of the saw-tooth points.

The nut of the missing bolt is normally installed against the outboard face of right arm assembly P/N 291089R. There was no deposit of grease on the outboard face of the bushing of the right arm, nor was there on the surface of this arm the heavy splatter of grease and dirt such as appeared on the left arm. Some grease was present, but only as a film. The outboard face of this bushing was unscarred except for slight concentric scratches. The outline of a washer could be seen on the face of the forging, but sufficient pressure had not been applied to remove the zinc chromate. The outboard one-third of the bushing's bore showed heavier corrosion than the other two-thirds and contained some irregular scoring. There were several threadlike score marks on the bore's inboard one-third from 9:00 through 3:00 o'clock. At several places near the 12:00 o'clock position these scorings were polished and flattened. The inboard face of the bushing was clean and a concentric impression of the link bearing was visible. There was a thin drag mark at the bushing's inner circumference at 9:00 o'clock, 0.005 inch wide by 0.10 inch long, parallel to the arm centerline. At the outer circumference of the bushing's inboard face at the 1:00 o'clock position there was a curved brinell mark 0.125 inch long by 0.015 inch wide. When viewed under magnification, another brinelling could be seen superimposed within the first one. The curvature of these marks, opposite in arc to the circumference of the bushing, exactly matched that of the circular end of the P/N 290790 link assembly. The flow of metal showed that both brinellings had been formed in a direction away from the bushing center. No elongation of the bushing hole could be found.

The bolt hole of link assembly P/N 290790, which is the bearing inner race, together with the bushings, was checked for roundness and found to be within tolerance. The bore was in excellent condition, although there was a slight brinell mark on the circular end of the link on the right side.

At impact, the four powerplants broke loose from their aft structure and their components were widely scattered in the wreckage area. The nose sections, with propeller hub dome assemblies still attached, were found a few feet ahead of each engine nacelle impact crater. Readings taken from the propeller dome settings and the propeller blade shim plates indicated that the propeller blades of each engine were set at an angle of from 29 to 30 degrees at the time of impact. Tests of the propeller governor components from each engine revealed a range of approximately 2,450 to 2,525 r.p.m. at impact.

There was no evidence of any operational failure or malfunction of any engine or propeller component.

N86511 was delivered to TWA in December 1945, and had accumulated 43,112 hours at the time of the accident. In addition to the routine major and base overhauls, there were two major repairs accomplished. The last repair was performed by the Lockheed Aircraft Corp. in the spring of 1951, and the aircraft had accumulated approximately 33,000 hours since this repair. In January 1958, the center rudder was replaced because of bad fabric. A base overhaul was accomplished at TWA's Kansas City Base in May 1959, at which time there was a routine replacement of the boost control units. The last base overhaul was performed during November 1960, at which time an elevator boost control replacement kit was installed. This kit included a parallelogram assembly and, therefore, the installation work required the removal and reinstallation of several bolts, including the AN-175-21 which connects the P/N 290790 link assembly with the lever arms. The last detailed controls inspection was made during the last scheduled periodic checks on August 7, 1961. These periodic checks included a visual inspection of the control components. All daily and turnaround inspections for August were accounted for.

Levels of carbon monoxide saturation in the tissue specimens of crew members were found to be less than 10 percent, the accepted high limit of normal; no alcohol was found.

Tissue specimens of passengers revealed even lower levels of carbon monoxide.

Analysis

There can be no doubt that the AN-175-21 bolt was missing from the parallelogram assembly when the elevator boost package was first examined. The problem demanding solution can be stated as follows:

> Was the bolt extracted by impact forces, or was it missing from its installed location prior to the crash?

First, to discuss the possibility of the bolt being torn out on impact, the geometry of the system is such and the resultant post-accident orientation of the parts was such that there could be only two ways to remove the bolt: (1) in double shear by displacing the P/N 290790 link assembly, and (2) by tensile load caused by spreading the P/N 291089L and R arm assemblies against the head and nut of the bolt.

The double shear possibility can easily be eliminated. There was no elongation of either arm assembly bushing; contra to elongation, the bushings were out-of-round by less than 0.2 percent. The fact that the bolt was missing is further proof that it was not sheared, since the ductility of the steel bolt and the bushings would allow sufficient deformation before fracture to seize the bolt sections.

The only remaining method of bolt removal on impact would be to place it in tension. The resulting failure would be either by tensile failure of the bolt or removal of the nut by thread strippage or by splitting the nut. If a shear nut were used, as a TWA witness testified, the thread strippage would be the more likely possibility. Since this requires the lesser tensile force, it is assumed that a shear nut was used in the installation and, thereby, the following argument is conservative.

The failure loads of the bolt assembly units are:

		Load, lbs. 3/
AN-175-21 bolt	- yield	4,890
AN-175-21 bolt	- ultimate	6,500
AN-320-5 nut	- ultimate	3,250
AN-380-2-2 cotter key	- ultimate	210

Since the cotter key failure load is low in comparison to the others, its additional strength to the system can be ignored without appreciably altering the results. It can be seen that the nut would fail well before the yield point of the bolt is reached; therefore, the load of concern here is 3,250 pounds.

Recalling that there were two heavy deposits of thick grease on the outboard face of the left arm assembly, it is now possible to calculate the pressure which would be applied to the surface of the deposit if the bolt assembly be placed in tension to the failure point. The geometry of the boost package assembly is such that the only way to place the bolt in tension is to spread the two lever arms apart, either in bending one or the other outward or in translating one of them away from the other. Either action places the outer face of the left bushing into contact with the bolt head, or it clamps between the bushing and the bolt head any object (washer and/or grease) in this path of action.

If the grease deposit originally covered the entire bushing surface, as it probably did, the pressure would be 28,300 p.s.i., an enormous amount of pressure to be withstood by a substance with the consistency of modeling clay. Since the grease, under pressure, could be extruded radially throughout 360 degrees, both toward and away from the bushing center, the fact that the deposit was still 0.10 inch or more deep is proof sufficient that no such pressure, or any appreciable fraction thereof was applied.

Because of the geometry and dimensions of the system, the gouges and scratches referred to earlier could have been made only after the bolt was extracted, releasing the link assembly. It was further noted that the chatter marks on the inner surface of the left arm could not have been made concurrently with the indentations on the bushings, nor could the indentations on the two bushings have been made simultaneously. There occurred at least four individual actions, three on the right bushing and one on the left, plus the multiple chatter marks shown on the arm assembly.

3/ These are tensile loads on the assembly, i.e., tension on the bolt, shear on the nut threads, and double shear on the cotter key.

Indications are that at some earlier time the bolt may have moved to a point where its end was about two-thirds into the bushing of the right arm of the lever assembly. This would provide some protection to the two-thirds of the bore, but expose the outer one-third to the atmosphere, allowing it to corrode. The thread marks at the inner one-third of the bore further indicate a partially displaced bolt. The thread impressions could not be made in this portion of the bore while the bolt was in a normal position.

In order for grease or any other material to build up on the outer surface of the left arm assembly bushing, there obviously must be a gap between the bushing and the bolt head (or washer). There are probably many ways to cause this gap but, in any case, regardless of initial cause, the nut must be loose by at least the number of threads equivalent to the maximum thickness of the grease, 1/64 inch.

The heavy deposit and the splatter in the vicinity of the left bushing appeared to have come, in the main, from the bushing bore, having been splattered out of the bushing by the loose, chattering bolt. In coming out, the oil or grease would have struck the bolt head (or washer) and been deflected radially. That portion depositing itself between the bushing and the bolt head (or washer) would have been packed down by motion of the bolt. The fact that no such deposit or heavy splatter existed at the other bushing would indicate that during a considerable period of time the nut was not in place, thus allowing oil to eject from the bushing and fall free.

Prior to the Civil Aeronautics Board public hearing there existed a question of how the grease deposit showed the hexagonal outline of a bolt head when Lockheed Aircraft Corp. drawing No. 209835 calls for two washers, one at the head of the bolt and one at the nut. It was evident that a washer had been present at one time because one had left its impression on the lever arm and could be seen after the grease was cleaned away. If the installation were made according to the LAC drawing, the hexagonal pattern could not have been present since an AN-960-516 washer has a greater diameter than the head of an AN-175 bolt. This apparent anomaly was cleared at the hearing when a TWA mechanic testified that because of tolerance variations, it was not always possible to secure the nut if a washer is installed under the bolt head. In such cases the washer is removed and the installation made without it. The Board does not suggest that this is an unsafe practice, but it does explain how the shape of a bolt head could be seen in the grease pattern. It is clear that a washer was used at this point on at least one previous parallelogram installation, but not on the one installed in November 1960.

The TWA mechanic further stated in his testimony that he installed the repair-kit linkage at the last base overhaul in November 1960. He also said, "I am sure all bolts were installed, properly torqued, and safetied . . ."; but subsequently added, "I do not remember specifically working on Plane 555 . . ." 4/

4/ TWA number for Constellation N86511

Since it has been shown that the AN-175-21 bolt was missing from its normal location at the time of impact, it becomes necessary to discuss the effect on the aircraft when the bolt is removed.

With reference to Appendix A, Fig. 6, it can be seen that pilot input moves link BC up or down which pivots link EDC as a walking beam about point D, causing point E to move down or up. This positions the control valve spool which is connected at point E. Elevator input moves link AD up or down which, in turn, pivots link EDC about point C. This action also positions the control valve spool. It should be noted that pilot and elevator inputs in the same direction are subtractive and inputs in opposite directions are additive to the valve spool.

If the AN-175-21 bolt at point A be removed, no support for the parallelogram is provided by link AD, and link EDC is free to pivot about point C. Since the valve is mounted in a near-vertical position, the weight of links AD and EDC and the weight of the spool are applied in the direction to move the spool toward up-elevator, to be resisted only by the friction in the valve and at points C and E, the total of which is negligible. Any friction above the normal would be overcome by vibration.

As soon as the valve spool ports fluid to the up-elevator side of the actuator, the elevator will start to move up, positive normal acceleration is applied to the aircraft which will drive the spool lower, more up-elevator pressure, more acceleration. It may therefore be seen that the entire operation from bolt extraction to maximum up-elevator hinge moment is almost instantaneous.

Further reference to the sketch shows that there can be no pilot input to the valve to counteract the action since the parallelogram can no longer pivot at point D. Input applied by the pilot is only carried through the mechanical linkage. The mechanical advantage of the system is far too low to be effective against the full pressure in the boost actuator. In a study 5/ of the Constellation boost systems, it was pointed out that the systems will develop approximately 8.5 times more hinge moment with boost on than with boost off. This factor is even greater with the above-described malfunction because the pilot does not have the added mechanical advantage gained by shifting to manual position.

5/ Report No. G8047.5, evaluation of elevator control system C/RC-121 aircraft July 13, 1961, by Temco Overhaul and Aerosystems, a division of Ling-Temco Electronics, Inc.

The only effective pilot action is to shift the elevator system to manual. This shift accomplishes three things:

1. Closes the boost cut-off valve;

2. Opens the bypass valve at the actuator; and,

3. Changes the mechanical advantage of the direct pilot-to-elevator linkage.

Therefore, it would appear that recovery from such a malfunction would be a simple, straightforward operation. There is a peculiarity of the system which can introduce a severe problem. That function of the shift-to-manual operation which changes the mechanical advantage of the system has the effect of lengthening the connecting system between the control column and the elevator torque arm. That is, the portion of mechanical linkage upstream of the shifting area (dual link rod) tends to move the control wheel aft, and that portion downstream tends to move the elevator downward. If the two hydraulic valves had operated properly, and there was no evidence in this case that they would not have, the elevator would have been free to move downward assisted by airload hinge moment; however, it there had been no forward pressure on the control column, the column would have been free to move aft, and the shift to manual could have been completed. If, however, the crew had applied forward pressure on the column while trying to shift, the shift would have become increasingly difficult in direct ratio to the amount of forward pressure.

The elevator has boost-on limits of 40 degrees up and 20 degrees down, but is further limited with increasing airspeed by boost hinge-moment maximum of 49,000 to 54,000 inch-pounds. In the manual position, elevator deflection is reduced to 16 degrees up and 6 degrees down because of the increase in mechanical advantage. Therefore, if shift to manual is started when the elevator is up more than 16 degrees it must be at or less than 16 degrees before the shift can be completed.

From this description of the system it can be seen that if the pilot responds normally to a stall, the following describes the events which will occur when the AN-175-21 bolt works out of the parallelogram:

1. When the bolt comes out, the weight of the spool and two of the parallologram links cause full pressure to be applied to the up-elevator side of the actuator.

2. The elevator travels up to its maximum hinge-moment. For the speed at which this aircraft was assumed to be operating, this would be less than 40 but greater than 16 degrees.

3. The aircraft enters an accelerated stall As this stall decays toward a primary stall, the elevator angle increases to 40 degrees.

4. The Captain or first officer, or both, would normally apply high forward pressure on the control column in an attempt to get the nose down.

5. While this forward pressure is being applied, the crew attempts to pull the shift handle.

6. With the elevator at its maximum deflection (maximum hinge-moment or 40 degrees, depending on speed) and held there by full hydraulic pressure and with forward (nose-down) force on the column, it becomes difficult, if not impossible, to move the shift handle far enough to operate the shutoff and/or the bypass valves.

7. With the aircraft stalled, or executing a series of stalls, even though altitude is being lost, the nose must be lowered to effect recovery; hence, increased forward force results in a higher force required to pull the shift handle.

8. Accelerated stall vibrations may cause empennage or rear fuselage damage. It will be shown later how accelerated stall is the known result of bolt extraction, and structural damage is a possible result of accelerated stall

There can be no doubt in the subject case that the elevator was at the 40-degree up position at some point during the empennage failure. The right outboard closing rib was crushed by, and left its impression on, the fin and rudder. Matching the parts showed clearly the 40-degree elevator position.

Following several accidents involving Navy R7V and Air Force C-121 aircraft (1049 models), the Air Force contracted with Ling-Temco to conduct an analysis of the Constellation elevator system. The Temco report indicates that when the shifting system was tested on a mock-up with simulated airloads, shift operation could not always be completed when 100 or more pounds of stick force was applied, or, if completed, it was done with high pull forces on the shift handle.

Following the fatal accident of a Navy R7V at Taft, California, on May 14, 1958, Lockheed Aircraft Corp. conducted similar tests and issued LAC Report 13142. This report shows that with extreme elevator deflections, shifting cannot be accomplished if it is resisted by large control forces. The report states, in part:

> "A study of the curves reveals the marked effect of column forces on shift force, but also that there is a reasonable amount of column force allowable." The report continues: "The conditions permitting a shift to manual have considerable latitude, depending upon surface moment, restraining column force, and surface angle. Within these limits many opportunities would be present permitting a shift to manual position." 6/

6/ Underscoring supplied.

The Board believes that opportunities-within-limits is a questionable approach to the design philosophy of an emergency system. When controls are jammed, particularly in an unmanageable regime, and if a corrective mechanism is available, a pilot should be offered a positive correction, not opportunities-within-limits.

As far as is known there have been no previous similar problems with the elevator boost system in the civil operation of Constellations, however, the military services have had an accident and an incident involving Constellations, the causes of which were attributed to similar elevator boost malfunctions and the inability to shift to manual.

The accident was the Taft case, referred to above. It was determined that clevis bolt, P/N LS-508-4-20, which connects the parallelogram linkage to the valve spool (Point E in Appendix A, Fig.6) backed out, separating the spool from the linkage. While this is not the same bolt as in the instant case, the effect is similar; the spool is free to move in either direction, but its natural tendency would be down (elevator up). Advocates of opportunities-within-limits should seriously consider the following facts regarding this accident.

1. The aircraft was observed by many witnesses to execute several 360-degree turns during which the aircraft pitched up several times, but never regaining all lost altitude. The general consensus was that when the nose pitched down, the wings were momentarily leveled or nearly leveled, followed by a pitchup and break to the left to steep bank angles.

2. Despite the fact that the aircraft descended in this manner from 13,000 feet, 12,300 above accident site, thus allowing several minutes for corrective action, the elevator boost system was still in the boost-on position at impact.

3. The crew was far from inexperienced. The record shows:

Crew Member	Total Time	R7V Time
Aircraft Commander	5674	1233
Copilot	4404	342
1st Flight Engineer	----	2088
2nd Flight Engineer	----	1052

4. In an apparent last-ditch effort to get nose-down pitching moment, the crew selected 80 to 100 percent flap.

The incident, the details of which were entered in the record at the public hearing, also involved an R7V. While the initial malfunction was of a completely different nature, the result was the same. The weight of the separated actuator piston ported the valve to the full elevator-up position. The aircraft executed five successive accelerated stalls and lost 3,000 feet of altitude before the system could be deboosted. The forces and accompanying vibrations caused serious structural damage to skin, stringers, and bulkheads in the aft portions of the fuselage.

Further proof that accelerated stall can produce structural failure is found in the records of R7V structural integrity tests. During one flight, the aircraft was inadvertently put into an accelerated stall. Inspection following the incident revealed that there was a complete separation of the right stabilizer rear spar web

This separation was located one-half a rib station inboard of the point at which the rear spar failure of N 86511 occurred.

Conclusions

The Board has attempted to show in this report how the physical evidence proves that the AN-175-21 bolt in the parallelogram was missing at the time of impact and further to prove that the loss of the bolt precipitated the accident. The effect of such loss has been explained and related to other accidents and incidents. It has also been shown how the accelerated stall resulting from bolt loss can produce structural failure similar to that of the TWA aircraft.

The Board concludes from the evidence at hand that during the climbout from Midway Airport, the AN-175-21 bolt worked its way clear of the parallelogram link. This was followed immediately by full pressure to the up-elevator side of the actuator piston. The pilot's natural response to the resulting violent pitchup and accelerated stall prevented successful shift of the elevator boost system to the manual position.

The manner in which the bolt was lost is largely a matter of conjecture. There are many possibilities. The nut could have been left off at the time of installation in November 1960, however, this is not probable in view of the length of time which elapsed from November 1960 until the occurrence of the accident. The shear nut could have been over-tightened, thereby stripping the threads, but the loads on the bolt are such that even a stripped nut, if it has a cotter key installed, could hold the bolt in place. The most probable reason, although it cannot be substantiated, is that the cotter key was omitted at the time of the parallelogram installation and that during the intervening months the nut backed off and allowed the bolt to come out. The immediate valve-porting, the rapid onset of hydraulic pressure to the boost actuator, and the resulting maximum hinge moment on the elevator associated with loss of this bolt prove conclusively that the loss could not have occurred prior to the climbout from Midway Airport.

On November 22, 1961, the Board recommended to the Administrator of the Federal Aviation Agency that the mechanism for shift-to-manual in the Constellation control boost system be modified so that the actions would be sequential rather than simultaneous. Specifically, under the recommended change, the shifting action by the pilot would remain one continuous motion of a handle but would, first, open the bypass valve; second, close the hydraulic shutoff valve and, third, shift the mechanical linkage. With such an arrangement, all hydraulic pressure in the boost package would be relieved prior to the mechanical shift action and would thus allow the complete shift-to-manual without restriction regardless of pilot-applied control forces.

On March 8, 1962, the Administrator advised the Board that his Agency was having the Constellation Flight Manual amended to include "procedures for turning off the elevator boost with an uncontrollable elevator." The Administrator further advised that "in view of the excellent service history achieved by this aircraft since certification in 1946, we believe there is insufficient justification to require design changes to accomplish your total objective."

Although turning off the elevator boost provides a possible means of regaining

control, it appears hopeful to assume that a pilot will recall and execute successfully the flight manual instructions when confronted unexpectedly with a violent structure-damaging maneuver instinctively resisted by pushing on the control wheel. The Board, therefore, recommended on August 24, 1962, that further consideration be given to modification of the shifting system.

Probable Cause

The Board determines that the probable cause of this accident was the loss of an AN-175-21 nickel steel bolt from the parallelogram linkage of the elevator boost system, resulting in loss of control of the aircraft.

BY THE CIVIL AERONAUTICS BOARD:

/s/ ALAN S. BOYD
Chairman

/s/ ROBERT T. MURPHY
Vice Chairman

/s/ CHAN GURNEY
Member

/s/ G. JOSEPH MINETTI
Member

/s/ WHITNEY GILLILLAND
Member

S U P P L E M E N T A L   D A T A

Investigation and Hearing

The Civil Aeronautics Board was notified of this accident on September 1, 1961. An investigation was immediately initiated in accordance with the provisions of Title VII of the Federal Aviation Act of 1958. A public hearing was ordered by the Civil Aeronautics Board and held in the Charles Continental House, Midway Hotel, Chicago, Illinois, on September 27, 1961.

Flight Personnel

Captain James H. Sanders, age 40, was employed by Trans World Airlines August 30, 1945, and was promoted to captain June 18, 1954. He had a total flying time of 17,011 hours, of which 12,633 were in Constellation equipment. His total instrument time was 3,242.30 hours. Captain Sanders held a FAA certificate and a currently effective airline transport rating No. 257341 issued June 10, 1954, on Douglas DC-3, Martin 202-404, and Lockheed Constellation. The date of his last physical was June 26, 1961, with no waivers. He had a rest period of 19 hours prior to subject flight. His last proficiency check was June 17, 1961, in a Lockheed Constellation and his last line check was on May 20, 1961. The date of his last emergency equipment review was June 16, 1961.

First Officer Dale Tarrant, age 31, was employed by Trans World Arilines December 5, 1955. His total flying time was 5,344 43 hours, of which 1,975 were in Constellation equipment Mr. Tarrant had a total instrument time of 340 hours. His rest period prior to subject flight was 19 14 hours. He held a currently effective FAA certificate with commercial license No. 1323998. His instrument rating was issued March 16, 1956. The date of his last FAA second-class physical was October 21, 1960, with no waivers His rest period prior to subject flight was 19 hours. His last proficiency check was May 17, 1961, in Lockheed Constellation equipment. The date of his last emergency equipment review was May 17, 1961.

Flight Engineer James C. Newlin, age 38, was employed by TWA May 21, 1951. He was promoted to flight engineer November 16, 1953 His total flying time was 5,816:54 hours in Constellation equipment. Rest period 24 hours prior to subject flight was 19:14 hours. Mr. Newlin held FAA A&E certificate No. 1210446 issued May 1, 1951, and FAA flight engineer certificate No. 1282233 was issued April 9, 1954. The date of his last physical examination was December 30, 1960, with no Class II waiver. His last proficiency check dated March 29, 1961, was in a Lockheed Constellation flight simulator. Flight Engineer Newlin's last line check was April 9, 1961, and the date of his checkout on Constellation equipment was April 12, 1954. His last emergency equipment review was March 29, 1961.

The two stewardesses were Barbara Jane Pearson and Nanette G. Fidger. Both had complied with all company requirements with respect to training.

APPENDIX A

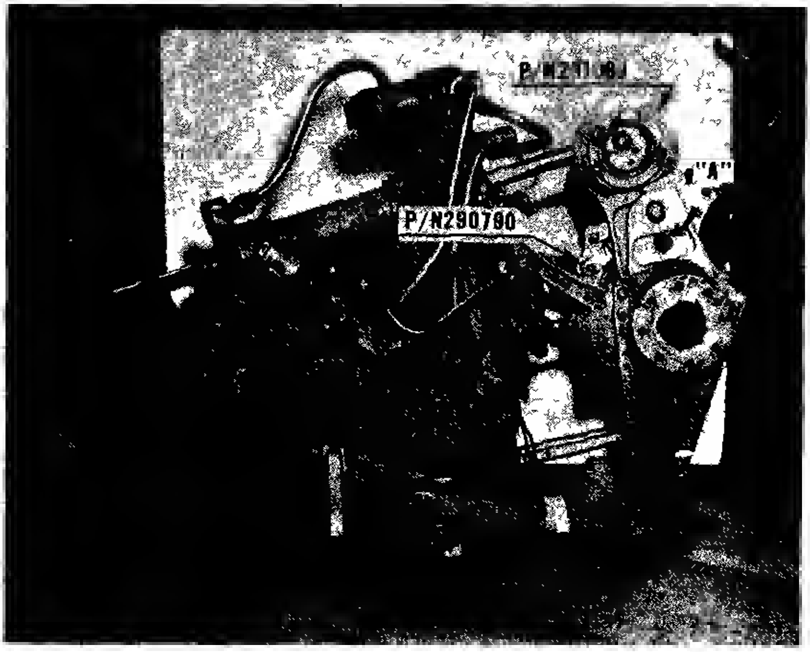

FIG. 1. Elevator boost package. Bushing where bolt should have been is indicated by arrow "A".

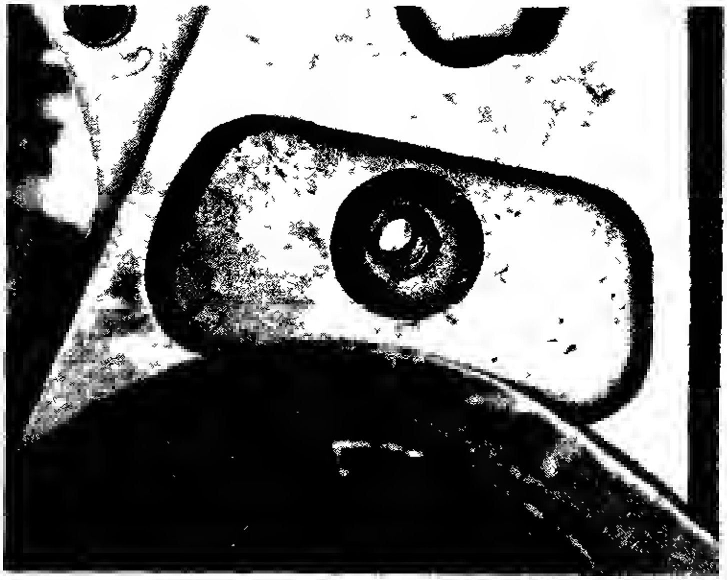

FIG. 2. Close-up view before disassembly of bushing against which head of bolt should have been.

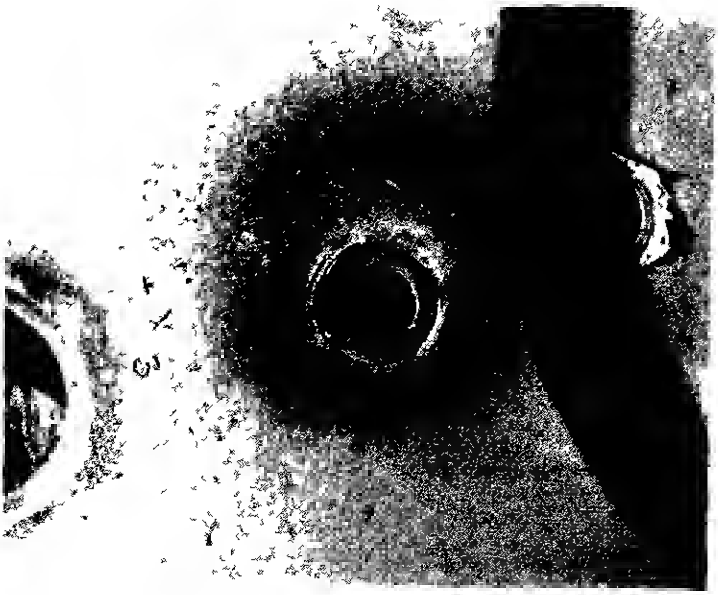

FIG. 3. Close-up view of bushing in Fig. 2, after disassembly but prior to cleaning.

FIG. 4. Close-up of bushing against which nut should have been. Taken after disassembly, but before cleaning.

FIG. 5. Parallelogram, removed from boost assembly but reoriented to its position before removal. Note grease ring at arrow, made by bushing face.

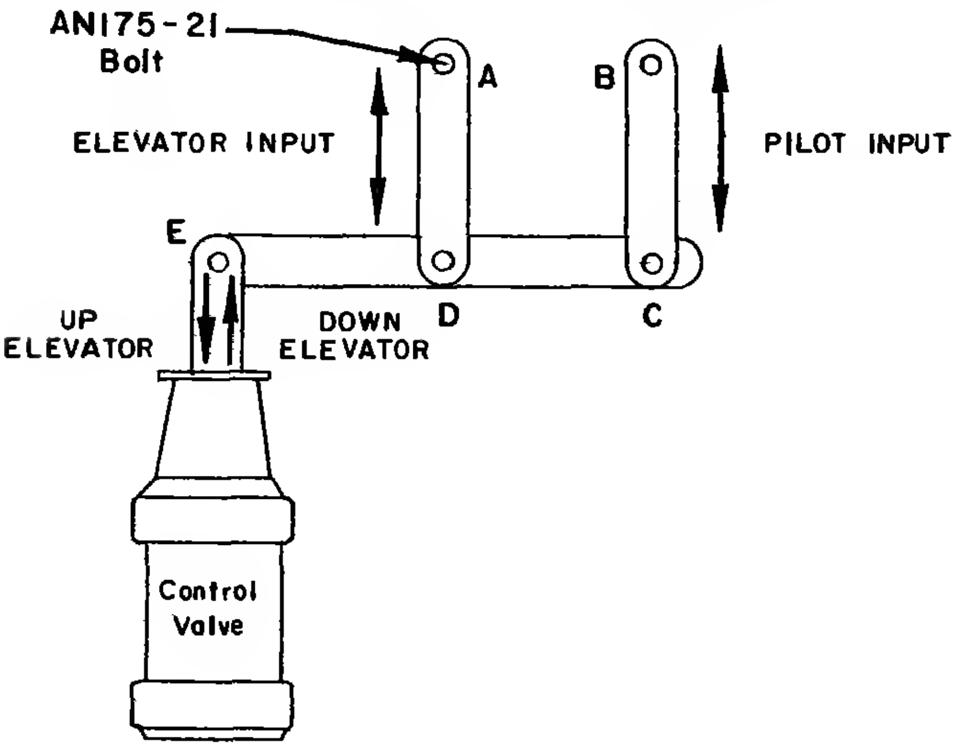

FIG. 6. Schematic diagram of parallelogram linkage and valve of elevator boost package.